III. *Some Observations on the Ova of the Salmon, in relation to the distribution of Species; in a letter addressed to* Charles Darwin, *Esq., M.A., V.P.R.S. &c.*

By John Davy, *M.D., F.R.S., Inspector-General of Army Hospitals.*

Received March 27,—Read April 26, 1855.

My dear Sir,

In a letter with which you have favoured me, that of the 28th of January, you did me the honour to ask my aid in an inquiry in which you take an interest, in common, as you remark, with most naturalists, viz. the geographical distribution of species, especially that of fish. At the same time you expressed your opinion that some useful information might be procured by experiments on the impregnated ova of the latter, were they so conducted as to show what the ova are capable of bearing without loss of vitality, and under exposure to circumstances such as might be compatible with their being conveyed from one river or lake to another, adhering, for instance, to the plumage, beak or legs of birds. In reply, I acquainted you of my willingness, should I have an opportunity, to accede to your wishes; and, that occurring, having been so fortunate as to procure the means of making some experiments likely to be elucidatory, I have now the pleasure of communicating the results obtained.

All the experiments I have to describe have been made on the ova of the Salmon, for which I have been indebted to two gentlemen, John Barker, Esq., of Broughton Lodge in Cartmel, and William Ayrton, Esq., of Chester. By the first, through one of his keepers, I was supplied with a considerable quantity of ova, taken from a breeding-bed in the Leven, a river that flows out of Windermere, and from a part of it near Newby Bridge, about eighteen miles distant from my house. Through the latter I obtained ova from Overton on the Dee, taken from boxes in which they had been placed in the process, as it has been called, of artificial breeding.

Both gentlemen were so good as to desire the keepers, in packing the ova, to attend to the directions I gave in writing, with the intent of commencing the inquiry even in the act of their being sent. Those from the Leven were divided into three portions; one, of 110 ova, was contained in an eight-ounce vial, two-thirds full of water, which was changed more than once on the way; another, of 75 ova, was enclosed in wet wool; and the third, of 62 ova, in dry wool. The latter two were in a small box, the lid on, which box as also the bottle were carried by hand. These ova reached me in about twenty-four hours from the time they were taken from the river, and were received on the 6th of February. They all appeared healthy and in

good progress of development, the eyes of the embryos being visible, and the blood-corpuscles distinct in the vessels of the vitelline membrane, when placed under the microscope, using a glass of one-inch focal distance. Without loss of time they were variously distributed; some in shallow earthenware pans, some in finger-glasses used at table, and with water in all little more than sufficed to cover them. No gravel was added. The water employed was well-water of considerable purity, of about 50° Fahr., and was changed once daily, and once only. The vessels were kept in a room, the temperature of which seldom exceeded 50°, and was rarely below 46°. Most of these eggs proved productive, and have yielded young and vigorous fish. The first which broke their shell appeared on the 15th of February, the last on the 17th of March: of the total number not more than three or four aborted.

The ova from the Dee were received on the 7th of February, conveyed by rail, and had been sent off the preceding day. One portion of them was in a two-ounce vial, two-thirds full of water; another, in a vial of the same size full of water; a third, in dry sand; a fourth, in wet sand; a fifth, in wet cotton-wadding; and a sixth, in dry wadding: all enclosed in a covered box. These ova on arrival exhibited no signs of organic development. They were distributed immediately much in the same manner as the preceding, and were treated in the same way, but with a different result. All of them in succession became opake from imbibing water, and not in a single instance were there any indications afforded of vital progress; leading to the inference that they were dead when they reached me. From Mr. Ayrton I have recently been informed that the ova remaining in the box from which those had been taken were doing well; and hence, necessarily, the conclusion, that the journey had been fatal to those I received. This may have been owing to their having been sent at so early a stage; and I may mention in confirmation, that a second supply which was forwarded to me later—three weeks later—sent by post in moist wool, in a more advanced stage, nearly as much advanced as those from the Leven, arrived alive and are now hatched. It may perhaps be said, that the treatment of the unsuccessful ova after I received them, especially as to the manner in which the water was supplied, was the cause of their failure: but this does not appear to me probable, having found it to succeed with the ova of the delicate Charr,—ova taken by myself from the parent-fish, and impregnated forthwith and immediately distributed in the same kind of vessels as those now used, and the water in which, of the same quality, was changed once only daily.

Having premised thus much, I shall now describe the several experiments which I have made for the purpose of testing the power of endurance of the ova. Unless otherwise specified, it is to be understood that the ova in each instance used were of those from the Leven.

I. *Of Exposure to the Atmosphere.*

1. An ovum exposed for an hour on a slip of glass to the air of a room at 64°, placed near a fire, became dry superficially without its circulation being stopped.

Returned to water, its circulation was distinct at the end of forty-eight hours. Nine days after it was in a dying state.

2. An ovum on a slip of glass was exposed to the air of a room at 52° for two hours. The shell then had become at one spot indented as from shrinking, the effect of evaporation, yet the circulation seemed unimpaired; but transferred to water, the circulation presently stopped, the egg becoming opake from the absorption of water, and of course dead.

3. An ovum exposed to the air of a room on a watch-glass from noon till 4 P.M., the thermometer rising from 49° to 51°, had become dry and shriveled. From the state of the shell the blood-vessels were indistinct under the microscope. Put into water, in one or two minutes a rupture of the shell took place and the young fish escaped. It was very languid, only the slightest indications of life being perceptible; yet the heart did not cease its feeble action till the eighth day, counting from the rupture of the shell.

4. An ovum on a support of glass was exposed to the air of a room at 49° for an hour and ten minutes; its shell was slightly indented. Returned to water, on the second day the young fish burst its shell, was vigorous, and so continued.

5. An ovum was exposed to the air of a room during the night for about ten hours, the thermometer under 50°. The following morning it was found shriveled; put into water, the shell presently burst; the young fish, excepting for a slight motion of its pectoral fins, appeared lifeless, and it soon died.

6. An ovum placed on a rock in the open air in the shade at 38°, after two hours was slightly shriveled and its circulation had become languid. The following morning its circulation had ceased, and it shortly became opake.

7. An ovum placed on snow during a thaw with occasional gentle rain, the air about 34°, and kept there from half-past nine in the morning till four in the afternoon, did not appear to be shrunk, nor was its circulation interrupted. Replaced in water, its circulation the following day was active.

II. *Of Exposure to Moist Air.*

To ascertain the effect of exposure to moist air, I have made many experiments, as by placing the wet ova in watch-glasses covered with other glasses of the same size; keeping them in moist wool, from which water had been wrung out; and in vials slightly wet within; in each instance taking the precaution to allow of the admission of air. The trials have been made at temperatures varying from 34° to 50°. The results have been so uniform that I do not think it necessary to enter into minute details. The ova in no instance appear to have materially suffered, whether the exposure has been for an hour or for several days. Thus, in one experiment, nine ova were kept in a vial, one of six-ounce capacity, eleven days; examined then under the microscope, the circulation in each of them appeared to be vigorous, as vigorous as before; and, replaced in water, they all produced healthy fish, and sooner on an

average than those constantly kept in water. These ova were from the Leven. In another experiment, with ova last received from the Dee, four were kept in a vial of the same capacity and merely moist within, fourteen days without apparently suffering; they were all hatched on being replaced in water. And, in a third trial, two ova, also from the Dee, have been kept in moist wool twelve days, also without any appearance of injury, these too having been hatched after having been put into water.

III. *Of Exposure in Air and Water to a Temperature at or below the Freezing-point.*

1. An ovum exposed on a watch-glass to the open air from 4 P.M. one day to 10 A.M. the following, the thermometer at 30° at the commencement and termination of the trial, had become slightly shriveled and its circulation was stopped; put into water with snow, so as to be gradually thawed if frozen, it did not revive; its death was denoted by its yelk becoming opake.

2. An ovum exposed to the open air at about 30° for an hour, was found adhering to the slip of glass on which it rested by a frozen drop of water, so that it could be carried inverted without falling off. Under the microscope, still attached to the glass by ice, the blood-corpuscles were seen in slow motion in the vessels; in one vessel they were moving backward and forward. Where adhering to the glass the ovum was slightly flattened. Removed to water, the following day the embryo was seen active and the circulation vigorous; thirteen days later the young fish burst its shell, and was to all appearance uninjured.

3. Another ovum, exposed to the open air of 29° for an hour and twenty minutes, was found frozen to the glass, but without loss of vitality. The result was the same as that of the preceding experiment.

4. An ovum exposed in water in a watch-glass to the open air during the night, the thermometer so low as 20°, was found in the morning included in ice and dead; the yelk had become opake and was probably frozen.

5. Exposed an egg in a wine-glass to the open air from 3 P.M. one day to 10 A.M. the next, the thermometer as low as 22°. The whole of the water was frozen; when thawed no circulation was visible in the ovum; two days after a feeble circulation was detected, which ceased the following day and the yelk became opake.

6. An ovum exposed in water to the open air, about 31°, in an hour was covered with a pellicle of ice; the circulation had become languid. An hour and a half later, the thermometer at 30°, the ovum was included in ice; the circulation much the same. The experiment was continued about eighteen hours longer, the ovum included in ice at about the same temperature; the circulation was now languid but distinct, and the ovum was nowise altered in appearance.

7. An ovum was exposed in water in a wine-glass to the open air below the freezing-point. When a pellicle of ice had formed on the water, the glass was surrounded with wool in a little box and left in the open air. During the night the thermometer fell to 9°. The ovum in the morning was found adhering to the bottom of the

glass by ice, and the inside of the glass was coated with ice, the greater portion of the egg however remaining in water. The ice thawed, the circulation was seen going on, and it soon became active. Twelve days after, the young fish burst its shell, was, and has continued vigorous.

8. An ovum was exposed in water to the open air at 28°. In about two hours the water was frozen at the surface and spicula of ice had formed round the ovum, as it were shooting from it. Thawed on the following day, the circulation was found to be vigorous, and in eleven days a young active fish was produced.

9. An ovum, one of those last received from the Dee, was exposed to the open air, placed on green moss, and left so exposed during three entire days and nights. It was then returned to water. In six hours after it was hatched. The young fish was languid and in point of size comparatively diminutive, as if prematurely produced, yet the action of the heart was vigorous, and the circulation as seen under the microscope normal. It may be right to notice the kind of weather that prevailed during the exposure of the ovum. During the first twenty-four hours the thermometer by day was between 36° and 38°; there was some rain, ·39 inch was the quantity, and partial sunshine; during the night the thermometer on the grass fell so low as 29°·5; there was a little rain, ·02 inch. During the second twenty-four hours the thermometer by day varied from 39° to 33°; the air most of the time was misty, but without rain; at night the thermometer fell to 28°, yet, as there was no frost in the morning, it was probably so low only for a very short time. During the last twenty-four hours, the state of atmosphere and the temperature differed but little from what they were in the preceding. Part of the time, especially during the latter third, the ovum was a good deal protected by the leaves of the moss, between which it had sunk. At the end of the three days it was neither dry nor shriveled, and only very slightly indented, and that on the point on which it rested. It is worthy of remark, that it was the first hatched of the ova last received from the Dee; and that the young fish, now six days old, is alive and thriving.

IV. *Of Exposure in Water to a Temperature of, or above* 70°.

In these trials ova were employed and young fish, and chiefly the latter, as better adapted to show the effect of the high temperature. In each instance the ovum or young fish was put into a thin glass vessel of the capacity of about four ounce measures, nearly full of water, and this vessel was placed in a water-bath of the temperature required. The temperature given in each following instance was that of the water in which the subject of the experiment was immersed.

1. An ovum kept two hours and a half in water at 70°, placed under the microscope, was found to have its circulation somewhat impaired, rendered more languid; kept in two hours more, the temperature rising to 80°, no further injurious effect was produced, at least that was apparent. The vessel was now withdrawn from

the bath and allowed to cool gradually. When next seen, ten hours later, a young fish had burst its shell and was vigorous.

2. An ovum and a young fish were kept in water between 68° and 72° about eight hours. The ovum, one of those from the Dee, was then found hatched, and the young fish produced was tolerably active. The following day both were exposed about nine hours to a temperature between 70° and 80°, rarely reaching 80°. At the end of this time they appeared languid, and when in motion disposed to irregular movements. Removed from the water-bath, on the following day they were active, and exhibited no peculiarity appreciable that could be attributed to the higher temperature to which they had been subjected. The ovum in its hatching in this instance preceded all the others from the Dee, with the exception of the one already mentioned, that exposed three days to the open air.

3. A young fish and an ovum were put into water which in the bath presently acquired the temperature of 82°, and in an hour rose to 85°. Now taken out and allowed to cool gradually, the circulation in the young fish was found to be very languid, the heart contracting feebly. The following day it was found dead. The ovum did not appear to suffer materially; three days after, it was hatched and a vigorous young fish was produced.

4. An ovum kept in water for two hours, at a temperature from 90° to 95°, lost its translucency, and opened under water was found to be dead.

5. An ovum, one of the last from the Dee, kept half an hour in water at 100°, afforded the same result.

6. A young fish was kept in water three hours, the temperature of which at the commencement was 70°; it rose to 85°, and when taken from the bath it had fallen to 82°. The heart then was acting with tolerable vigour, and the day following the fish appeared to be nearly in its usual state: five days later it was alive and tolerably active, but less vigorous than those which had not been so exposed.

7. A young fish kept in water an hour at 84° was found dead. No action of the heart was perceptible nor of any of the muscles when it was taken out. Another young fish was put into the water when cold without experiencing any bad effect. This trial was made to be certain that the fatal effect was not owing to want of air in the water.

8. A young fish was kept in water rising in temperature from 78° to 81° three hours and a half without any permanent bad effect that was appreciable. When taken out it appeared torpid, but the heart was acting well. Two days after the fish was as active as before.

9. A young fish, kept two hours in water between 88° and 90°, was, when taken out, dead.

10. A young fish, kept only a few minutes in water at 92°, appeared to be dying when taken out; the circulation in its tail was stopped and the heart was acting feebly;

in about a quarter of an hour it ceased to act. The following morning the fish had a sodden appearance, and its disintegration had commenced.

11. A young fish was put into water at 80°; after three hours, when the temperature had risen to 85°, it appeared to be dead; its body was bent and it had become pallid. Under the microscope the heart was seen acting feebly, and the circulation was proportionably languid. On the following day the body had become unbent; the circulation in the tail had ceased, but the heart was still acting feebly. Two days later the heart's action had ceased, and the only vestige of life was indicated by a just perceptible motion of the lower jaw, which was protracted three days longer.

12. A young fish was kept in water gradually rising from 78° to 88° for three hours. At 85°, the heart acting, no circulation was perceptible in the tail; at 88° the body had become bent and pale, and the heart's action arrested.

V. *Of the Effect of Salt and Brackish Water.*

1. An active young fish and an ovum in which the circulation was vigorous, were put into a solution of common salt of the specific gravity 1026, which it may be conjectured is nearly the degree of saltness of the sea at the estuaries of our salmon rivers. The fish immediately became restless, and the heart's action accelerated. At the end of five hours it appeared to be dying; the heart's action had become so languid as not to suffice for the circulation; notwithstanding, life was not entirely extinct, as was indicated by a feeble motion of the lower jaw, till about forty-eight hours from the commencement of the experiment. The dead fish was colourless and contracted in all its dimensions, and shortened at least one-third of its length.

The effect of the salt water on the ovum was equally fatal, but judging from the circulation, life was protracted in it a few hours longer.

2. An active young fish was put into a solution of common salt of the specific gravity 1016. It lived about four days, the heart's action gradually becoming feebler till the circulation ceased. When dead there was an accumulation of blood in the large vessels, and, as in the former instance, a diminution of the bulk of the fish, as if from contraction. The saline solution, it may be remarked, was changed daily so as to be sure that death was not owing to, or had been hastened by, deficiency of air.

3. A young fish was put into a solution of salt reduced to the specific gravity 1007, so as to be only slightly brackish. Immediately on immersion it showed great restlessness and increased activity, which continued with little abatement for several days. It has now been in the solution ten days. During the two last its activity has diminished, and at times it has appeared to be dying. It is rather more changed in form than the fish of the same age left in spring water, and the vitelline sack is decidedly more diminished, as if from increased vascular action produced by the stimulus imparted by the solution.

4. An ovum from the Dee, the circulation in which was active, was put into saline

water of the same specific gravity as the last. It was hatched at the end of about forty-eight hours. The young fish was at first languid; now, on the fourth day, it is little altered; it is seen commonly lying on its side, and is restless only by fits and starts.

Besides the experiments above detailed, I have made others, but differing so little in their results, that I do not think it necessary to describe them even in confirmation.

VI. *Concluding Remarks.*

On the conclusions which may be drawn from the experiments as bearing on the subject under consideration I shall be very brief; for the sake of order I shall advert to each section.

From the experiments detailed in the first section, it would appear that the ova of the Salmon in an advanced stage can be exposed to the open air, if dry, but a short time, at ordinary temperatures, without loss of vitality; but for a considerable time, if the temperature be low and if the air be moist; the limit in the former case not having exceeded an hour, whilst in the latter it has exceeded many hours.

From the experiments in the second section, it would appear that the vitality of the ova was as well preserved in air saturated with moisture, as it would have been had they been in water.

From the experiments in the third section, it would appear that the ova might be included in ice without losing their vitality; but that if exposed to a temperature many degrees below the freezing-point, probably effecting their congelation, they were deprived of their vitality.

From the experiments in the fourth section, it would appear that both the ova and the young fish were capable of bearing a temperature of about 80° or 82° in water for a moderate time with impunity, but not without loss of life at a higher temperature, any exceeding 84° or 85°.

From the experiments in the fifth section, it would appear that a degree of saltness of water equal, or nearly equal, to that of sea-water is pretty speedily fatal both to the ovum of the Salmon and to the young fish; that the same effect is produced on the young fish by brackish water of specific gravity 1016, but in a longer time; and that when the solution is so diluted as to be reduced to the specific gravity 1007, the advanced ovum may be hatched in it, and the life of the young fish may be sustained in it for many days, but with diminishing power.

Finally, in reference to the distribution of species, do not many of the preceding results render it probable, in the instances of fish of the salmon-kind, and by analogy of other kinds, that it may be effected in the manner you have suggested in proposing the inquiry, viz. by means of impregnated ova conveyed by animals, whether birds or quadrupeds, adhering to some part of their body, such as their feathers or hair, feet or mouth,—by the latter provided the temperature do not exceed 84° or 85°? And, during rain or snow, are we not warranted in concluding that an ovum may be taken

from one river to another without loss of vitality by an Otter or Heron or other aquatic bird, if lodged in the mouth of the one—with the proviso mentioned above, —or in the bill of the other; or during a time of frost or snow if adhering to the feet of either of the animals mentioned?

When my attention was first given to the subject, which was before I was favoured with your letter, I imagined that the impregnated ova might be conveyed in the stomach of birds, taken up from one river, and, it might be, disgorged in another, without loss of vitality, inasmuch as the ova of the Salmon found in the stomach of a trout have been known to be productive when returned to water. For an authenticated instance of the kind, I may refer to a report by Mr. HALLIDAY, the agent of Messrs. EDMUND and THOMAS ASHWORTH, on the artificial process of breeding Salmon carried on at Oughterard in Galway*. It was to test this conjecture that the experiments in the fourth section were made; and, I may add, with negative results, knowing as we do, that the temperature of the stomach of birds is usually above 100° of FAHR.

Besides the main and express object for which the preceding experiments were made, I trust the results may be of some use in aiding to solve the question as to the period, the age, at which the impregnated ova of fish are most retentive of life, and consequently, are in the state best fitted for transport without loss of life; and that those in the two last sections may help to explain the absence of the Salmonidæ in tropical seas and in those approaching to them in temperature, such as the Mediterranean; and may also throw a little light on some of the peculiar habits as well as on the localities of their migratory species.

I am, my dear Sir, yours very truly,

Lesketh How, Ambleside,
March 21, 1855.

JOHN DAVY.

* The Report is attached to "A Treatise on the Propagation of Salmon and other Fish," by EDMUND and THOMAS ASHWORTH: London, SIMPKIN and MARSHALL, 1853.